ANNUAL REPORT TO NATIONAL MARINE FISHERIES SERVICE

For

Examination of Local Movement and Migratory Behavior of Sea Turtles During Spring and Summer Along the Atlantic Coast Off the Southeastern United States

by

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Executive Summary

Since Federal FY2003, the SCDNR has conducted satellite-telemetry research with juvenile loggerhead sea turtles collected from the Charleston, SC, shipping entrance channel, in order to better understand seasonal and inter-annual distributional patterns of juvenile loggerheads in the Southeastern U.S. Understanding the movement and migration patterns of juvenile loggerheads, which comprise the majority of sea turtles collected in the water regardless of gear type, may have direct bearing on tag-recapture rates which may be used to estimate population size. Of 34 non-rehabilitated juvenile loggerheads satellite-tagged and released near Charleston, SC, all but three remained on the continental shelf off SC during the summer and fall. Furthermore, 11 of 14 juvenile loggerheads which have been monitored through most of the winter have also remained on the continental shelf, though further offshore, primarily off SC and GA and to a lesser extent off the NC and FL coasts.

During 2006 and 2007, an assessment of reproductive activity and seasonal distribution patterns of adult male loggerheads collected from the Port Canaveral, FL, shipping entrance channel was initiated. Satellite-transmitters were ultimately attached to 29 adult male loggerheads, of which all but one were monitored for at least one month following tag and release. Emigration away from Canaveral was rapid and occurred between the end of May and early June in both years. Of 24 adult males tracked through at least the end of June, 15 migrated away from Canaveral and nine remained resident. Migrants dispersed along the Eastern Seaboard between SC and NJ; to the FL Keys and Bahamas; and along the FL panhandle in the Gulf of Mexico. In contrast, residents in both years simply moved offshore to the middle and outer continental shelf off Canaveral. A greater proportion of migratory males were collected during the end of April 2007 than the beginning of April 2007, whereas mid-April collections in 2006 were nearly evenly split between migratory and resident males.

Documentation of both resident and migratory individuals, which may be independent of reproductive activity, was a key finding for this research. All but four of 40 adult male loggerheads that were evaluated using at least one reproductive metric in this study were considered to be reproductively-active, with reproductive-activity documented for both resident and transient individuals. High serum testosterone values were indicative of reproductive activity, and low serum testosterone values represent reproductive in-activity, despite small and rapid changes in serum testosterone values that can occur due to stress. Improved familiarity and experience with the ultrasound equipment rendered this technique especially valuable as a non-invasive means for confirmation of reproductive activity; however, inconclusive ultrasound imagery does not always indicate reproductive in-activity. The extent of plastron softness and de-keratinization also appears to provide a non-invasive and easily quantifiable metric for determining reproductive activity. In conclusion, data collected during this study in just three research cruises provide tremendous advances in the understanding of the reproductive physiology and life history of adult male loggerheads in the Western North Atlantic, which has implications for loggerhead populations elsewhere in the world as well as for other sea turtle species.

Introduction

Loggerhead sea turtles (*Caretta caretta*) inhabiting coastal waters along the southeastern United States represent the progeny of multiple rookeries (Bowen et al., 1993; Sears et al., 1995; TEWG, 2000; Maier et al., 2004). Tagging studies of nesting female loggerheads suggest that most return to the same beaches in successive breeding seasons (Bjorndal et al., 1983) and it is widely accepted that most females return to their natal regions to nest. Although considerable effort has been expended to study adult females on nesting beaches, much less is known about the distribution patterns of juveniles and adult males in coastal waters.

Prior to May 2000, in-water studies targeting sea turtles were primarily conducted at shipping entrance channels (Kemmerer et al., 1983; Standora et al., 1993a,b; Dickerson et al., 1995; Keinath et al., 1995) or at opportunistic inshore collection areas such as where pound nets are located (Byles, 1988; Epperly et al., 1995; Morreale and Standora, 1993). The need to conduct "…long-term, in-water indices of loggerhead abundance in coastal waters" (TEWG, 1998) led to the development of a regional in-water survey of loggerheads during summers 2000-2003 (Maier et al., 2004). Coastal waters 1-15 km offshore between Winyah Bay, SC, and St. Augustine, FL, were sampled in a nearly simultaneous manner using three research vessels annually. High catch rates were reported (Maier et al., 2004); however, very low recapture rates (<2%) were also reported, the cause of which was not readily evident.

Beginning in May 2004, in an effort to better understand the seasonal distribution patterns of juvenile loggerheads collected in coastal waters sampled during the 2000-2003 regional survey, the focus of the in-water survey was modified to intensively target one small trawling area to: (1) examine the effect of intensive trawling on recapture rates and (2) quickly obtain an adequate sample size of turtles to outfit with satellite transmitters. Prior to 2004, satellite telemetry had only been attempted with four juvenile loggerheads (NMFS 1; USACOE; Whalenet) and seven adult male loggerheads (Keinath, 1993; NMFS 2) south of Cape Hatteras; thus, long-term information on habitat utilization of juveniles and adult males in coastal waters was virtually non-existent for this region.

In order to facilitate historical comparisons of catch-per-unit effort (VanDolah and Maier, 1993; Dickerson et al., 1995), the shipping entrance channel of Charleston harbor was selected for this trawl survey. Logistical considerations, including close proximity to a turtle rehabilitation facility at the SC Aquarium in Charleston, also contributed to the decision to restrict trawling to this location. In April 2006, a second trawling area (the Port Canaveral, FL, shipping entrance channel) was added to this study to facilitate collection of adult male loggerheads (during their presumed mating aggregation) to provide new data on their reproductive biology and distributional habits.

This annual report highlights the major findings for research activities primarily carried out during 2007. More detailed analyses will be included in the 2004-2008 Final Report and manuscripts which will be submitted for peer-review in 2009.

Methods

Study Areas

In April 2007, trawling was conducted for 10 days between channel markers "1/2" and "9/10" in the shipping entrance channel to Port Canaveral, FL (28°23'N, -80°32'W; Figure 1). In addition to doubling the 2006 sampling effort, sampling was split between two cruises (2-6 April and 25-29 April) to evaluate potential short-term temporal differences in the reproductive physiology of adult males within the mating season. Fifteen minute trawls (bottom time) were conducted between subsequent channel markers (1 to 3; 3 to 5; etc.). Due to the principal objective of collecting adult male loggerheads as quickly as possible, opportunistic (rather than randomized) sampling was employed.

Trawling was conducted for two three-day cruises (in May and August 2007) in the Charleston, SC, shipping entrance channel (32°42'N, -79°48'W; Figure 2) , between channel markers "17/18" and "13/14". Seven of 12 index stations first utilized in 1990-1991 (VanDolah and Maier, 1993) and sampled for this research since 2004 were again utilized; however, to expedite collection of turtles, stations with the highest probability of turtle collection (based on 2004-2006 data) were targeted, rather than systematically sampled. Trawl bottom time ranged from 9 to 18 minutes.

Sampling was conducted aboard 75' double-rigged shrimp trawlers (R/V *Georgia Bulldog* in Canaveral; R/V *Lady Lisa* in Charleston) towing at speeds of 2.5-3.0 knots. Standardized NMFS turtle nets (for surveys associated with channel dredging operations) were utilized: paired 60-foot (head-rope), 4-seam, 4-legged, 2-bridal; net body is of 4" bar and 8" stretch mesh; Top's sides of #36 twisted with the bottom of #84 braided nylon line; 60' corkline to cod end; cod end consists of 2" bar and 4" stretch mesh.

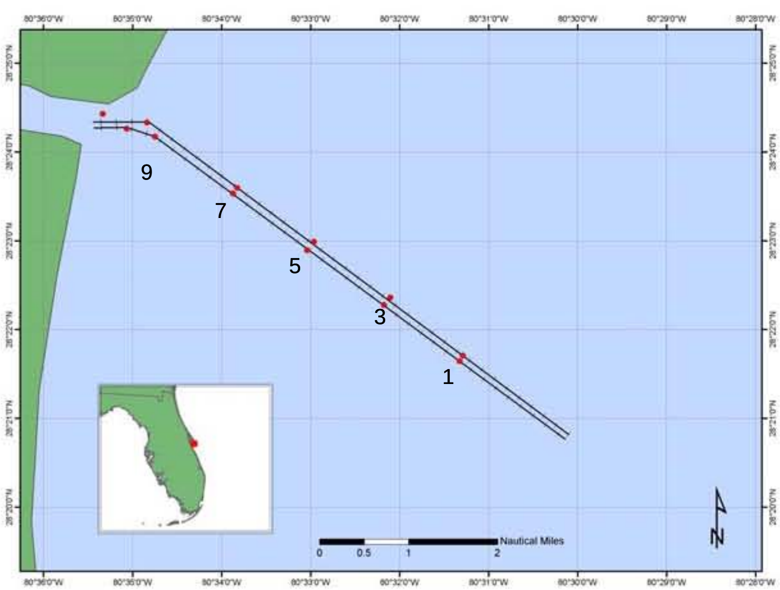

Figure 1. Trawling stations utilized for the collection of adult male loggerhead sea turtles in the Port Canaveral, FL, shipping entrance channel during April (2006-2007).

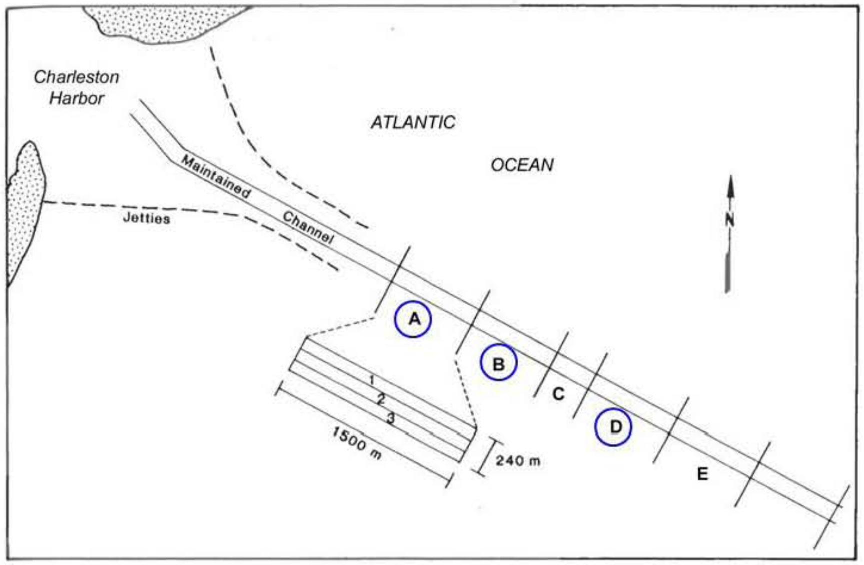

Figure 2. Index trawling blocks (VanDolah and Maier, 1993) in the Charleston, SC, shipping entrance channel sampled in 2004-2007 (blue circles).

Capture and General Processing

Turtles were immediately removed from nets and examined for life-threatening injuries, before being visually/electronically scanned for existing tags. If not previously tagged in this study, a sequential project identification number was assigned to each turtle.

Blood samples were collected for all sea turtles >5kg body weight with a 21ga, 1.5 in. needle from the dorsal cervical sinus of loggerhead turtles as described by Owens and Ruiz (1980). Blood samples consisted of a maximum of 45 ml total volume and did not exceed the total recommended volume (10% of total blood volume) based upon total weight as described by Jacobson (1998), who estimated that total blood volume in reptiles was 5 to 8% of total body weight. Blood samples were used as follows:

- Genetics - 5 ml (University of South Carolina & University of Georgia)
- Sex determination - 10 ml (University of Charleston)
- CBC/Blood chemistry -- 3 ml (Antech Diagnostics)
- Toxicological screening and immunological bioassay – 20 ml (National Institute of Standards and Technology; Medical University of SC)

A suite of standard (Bolten, 1999) morphometric measurements were collected for all sea turtle species. Six straight-line measurements (cm) were made using tree calipers: minimum (CLmin) and notch-tip (CLnt) carapace length; carapace width (CW); head width (HW); and body depth (BD). Curved measurements of CLmin, CLnt and CW were recorded using a nylon tape measure. Additional curved measurements included plastron width (PW), and two tail length measurements (tip of plastron to tip of tail (PT) and tip of cloaca to tip of tail (CT)). Body weight (kg) was measured using spring scales; turtles were placed in a nylon mesh harness and carefully raised off of the deck.

All sea turtles >5kg received two Inconel flipper tags and one Passive Integrated Transponder (PIT) tag (Biomark, Inc.). Triple tagging minimized the probability of complete tag loss. Inconel flipper tags were provided by the Cooperate Marine Turtle Tagging Program (CMTTP). Per instructions provided by the CMTTP, tags were cleaned to remove oil and residue prior to application. Inconel tag insertion sites, located between the first and second scales on the trailing edge of the front flippers, were swabbed with betadine prior to tag application. PIT tag insertion points, located in the right front shoulder near the base of the flipper, were swabbed with betadine prior to intramuscular injection of the sterile-packed PIT tag.

Prior to releasing turtles, a digital photograph of each turtle in a standard 'pose' (dorsal surface exposed, taken looking from anterior to posterior) was recorded. Additional photographs of unusual markings or injuries were also recorded.

Laparoscopy and ultrasound
Ultrasonography and laparoscopy were specialized sampling methods used only with adult male loggerheads. Ultrasonography is a noninvasive technique (Owens, 1999) commonly used in human medicine that allows the imaging of gonadal tissue and takes a maximum of 15 minutes per turtle. Laparoscopy is an invasive procedure that requires local anesthetic and highly sterile surgical techniques. Both procedures were performed while turtles were restrained in dorsal recumbency in a specialized restraining chair borrowed from the Florida Fish and Wildlife Commission, and while the research vessel was tied up at the dock, to provide a stable working platform.

For ultrasonography, the probe was placed on the inguinal region cranial to the hind leg. A coupling gel was used to insure transmission of the ultrasonic signal. Determination of reproductive activity status (i.e., whether an individual had or was preparing to breed) was made during the scan, but digital images of gonadal tissue were saved for posterity.

Direct viewing of the gonads was done using standard laparoscopy procedures developed for marine turtles and used successfully in the field by sea turtle researchers worldwide (Owens, 1999). Laparoscopy enables direct viewing of the testes and epididymides (in color vs. black and white imagery); thus, reproductive stage can be determined, providing a necessary validation of ultrasound images.

Turtles were prepped for laparoscopy in typical manner for surgery, including multiple scrubs of surgical site alternating between chlorohexadine scrub and 70% alcohol. Betadine solution was applied to the site as a final surgical prep solution. The surgical site was completely draped with sterile gowns, typical of any human/animal surgical procedure. A local anesthetic (2% lidocaine) was injected locally to the surgical site prior to making a small incision (~0.5 – 1cm) with a sterile scalpel blade, through which the laparoscope was inserted, allowing view of the gonads. Using biopsy forceps, a small piece of testicular tissue (2 to 6 mm^3) was removed and preserved for histological examination. Incisions were sutured with sterile absorbable 3-0 violet monofilament and a small amount of super glue was applied to the incision site. These procedures lasted ~40 min from surgical site preparation to incision closure.

Upon completion of surgery, turtles were carefully transported to circular (~500 gal) tanks on the boat or on shore using a lifting net made of small nylon mesh webbing, after which the tanks were filled with seawater. Turtles were closely monitored to evaluate breathing and diving capability. Once normal buoyancy was confirmed (which in some instances required holding turtles overnight), turtles were lowered into a 21' Privateer (tied along side of the larger research trawler) for satellite tag attachment and/or transport to the ocean (40 min each direction due to no-wake zone requirements) for release.

Satellite telemetry
ST-20 (Telonics, Inc) satellite transmitters were attached directly to the second vertebral scute on the turtle carapace using epoxy (Papi et al., 1997; Polovina et al., 2000; Griffin, 2002). Prior to attachment, barnacles and other organisms were removed with a chisel, the carapace was sanded, washed with betadine and dried with acetone. A roll of 1.0 cm diameter "Sonic Weld" (Ed Greene & Company; Sparta, TN) was placed around the bottom edge of the transmitter to form a well, followed by application of "Fast Foil" epoxy (Power Fasteners Inc.; New Rochelle, NY) to the entire bottom surface of the transmitter within the well using a caulking gun. Turtles were released approximately two hours after initial collection in close proximity (<3 km) to where originally collected.

Satellite telemetry data consisted of (1) geographic position at each surfacing; (2) water temperature at each surfacing; and (3) four descriptive dive cycle metrics for each of four, six-hour collection periods per day: time(s) of last dive; number of dives per collection period; mean dive duration(s) per collection period; and percent of time submerged per collection period. Satellite telemetry data were automatically processed, distributed and received by the Argos system. Daily data e-mails were sent to project personnel; however, data were primarily managed using "STAT" (Satellite Tracking and Analysis Tool; Coyne and Godley, 2005). Data were downloaded from "STAT" monthly to a relational database (MS Access) on a local area network for analyses.

By-catch
Large mesh nets result in low levels of by-catch relative to small mesh nets; however, by-catch were identified to the lowest possible taxon and a count or estimate of abundancenoted whenever possible. Sex and appropriate length (cm) measurements were included for all elasmobranches, as well as for finfish and invertebrate species of interest. Particular emphasis was placed on by-catch species that represented potential sea turtle prey items, such as blue crabs (*Callinectes sapidus*) and horseshoe crabs (*Limulus polyphemus*). Due to the specialized nature of this research and the desire to return by-catch to the sea as quickly as possible (to increase probability of survival and to provide safer working conditions on the deck), cataloguing of by-catch received lower priority in 2007 than with respect to the regional survey of 2000-2003 (when only standard turtle processing methods were utilized). Thus, although selected by-catch results are presented in this report, data were not always quantified and include estimates of total by-catch collected.

Results

Capture and Recapture, Canaveral

Fifty-nine loggerheads were collected in 23 trawling events (11.2 net-hours) in the Port Canaveral shipping entrance channel during 2-6 April 2007. Of 59 loggerheads collected, 44 were juveniles, 12 were adult males, and three were adult females. Among juvenile loggerheads, one was dead and badly decomposed when collected, and 28 others either escaped or were released without processing. Two adult males were not satellite-tagged due to pre-existing injuries such as a missing rear flipper (which also prevented laparoscopy) and damage to the V1 carapace scute where the transmitter is attached.

Seventy-one loggerheads were collected in 25 trawling events (11.5 net-hours) in the Port Canaveral shipping entrance channel during 25-29 April 2007. Of 71 loggerheads collected, 48 were juveniles, 19 were adult males, and four were adult females. Among juvenile loggerheads, one was dead and badly decomposed when collected, and 43 others either escaped or were released without processing. Of 20 adult males collected, one escaped and was not able to be processed; two represented short-term (1 to 19 days) recapture events of satellite-tagged males; and a third (CC2452) represented a long-term (391 days) recapture event of a formerly satellite-tagged adult male.

Capture and Recapture, Charleston

Seven juvenile loggerheads (58.5 to 70.7 cm SCLmin) were collected during 16 sampling events (5.8 net-hours) in the Charleston Harbor shipping entrance channel on 21-22 May 2007. One loggerhead collected was excluded for consideration for satellite-tagging due to blood levels which suggested this turtle was sick (though not sick enough to warrant shore-based care). The six remaining loggerheads collected were satellite-tagged.

Seven juvenile loggerheads (60.8 to 76.8 cm SCLmin) were collected during 23 sampling events (9.0 net-hours) in the Charleston Harbor shipping entrance channel on 31 July and 1 August 2007. Two loggerheads were excluded from consideration for satellite-tagging for this study: the first (CC0439) because the carapace was too “spongy” for transmitter attachment and the second (CC0440) because it required transfer to the SC Aquarium for treatment for “Debilitated Turtle Syndrome (DBS)” (incidentally, this second turtle was released from the SC Aquarium with a satellite transmitter as part of a SC Aquarium study three months later). A second loggerhead (CC0408) was also transferred to the SC Aquarium due to a prolapsed cloaca and an invasive stingray spine penetration in the front left flipper; this turtle was released from the SC Aquarium in August 2007 with a satellite transmitter as part of this study. Incidentally, this turtle was previously collected in our study in May 2006; however, no discernable growth was evident during the 437 days at large between initial capture and recapture.

Catch variability, Canaveral

During 2006 and 2007, trawling was conducted in four blocks between channel marker buoy pairs “1/2” (offshore) and “9/10” (inshore). Only one trawling event occurred between buoys “7/8” and “9/10” and no adult male or female loggerheads (but one juvenile loggerhead) were collected there (Table 1). Catch rates for adult male loggerheads were greatest between buoys “3/4” and “5/6”, with 27 of 41 (66%) adult males collected in 32 trawling events between those buoy pairs. In contrast, catch rates for adult females were greatest between buoys “5/6” and “7/8”, with 6 of 9 (67%) adult females collected in 21 trawling events between those buoy pairs. Catch rates for juvenile loggerheads were also greatest between buoys “5/6” and “7/8”, with 59 of 106 (56%) collected in 21 trawling events between those buoy pairs.

Table 1. Spatial variability in size and sex of loggerhead sea turtles collected from the Port Canaveral, FL, shipping entrance channel during April 2006 and 2007.

Block	Events	Net hours	Adult Male	Adult Female	Juvenile
1 & 3	7	3.5	2	1	7
3 & 5	32	14.74	27	2	39
5 & 7	21	10.5	12	6	59
7 & 9	1	0.5	0	0	1

Catch variability, Charleston

Seasonal and inter-annual variability in loggerhead catch rates were evident between 2004 and 2006; however, similar (and low) CPUE was noted for both May and August 2007 (Table 2). In contrast to trends noted during 2004-2006, CPUE among four stations targeted in 2007 was greatest on the “red” side of the channel (stations B1 and D1) as opposed to the “green” side of the channel (stations B3 and D3).

Inter-annual differences in surface water temperatures at the time of sampling in May have been noted since 2004, despite attempts to schedule sampling in a consistent manner (i.e., the 2nd and 3rd weeks of the month). Greatest loggerhead catch rates were noted in May 2004 (Figure 3), when the warmest May water temperatures were also noted. Variable but similar May water temperatures were noted during 2005, 2006 and 2007.

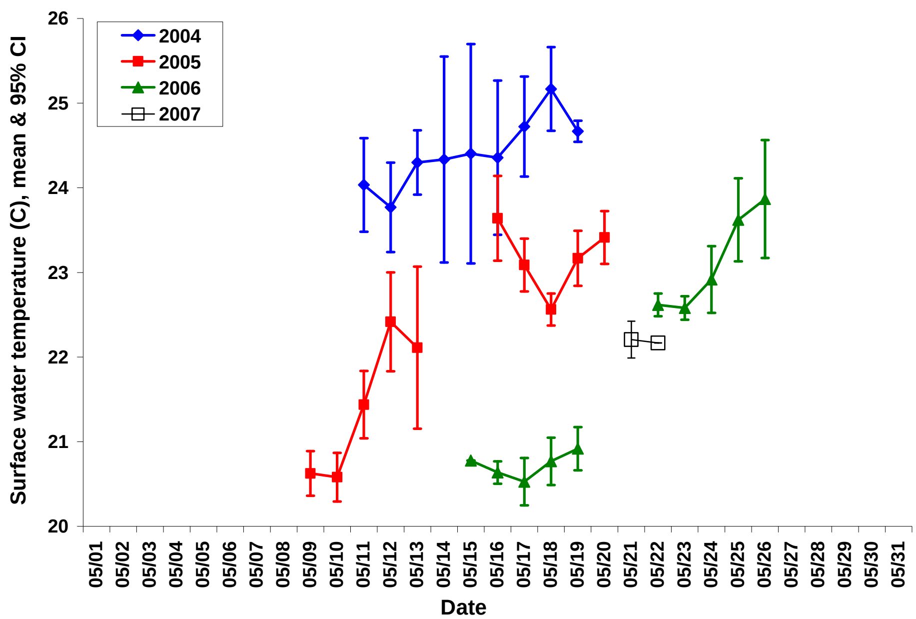

Figure 3. Mean (and 95% C.I.) daily surface water temperatures in May 2004-2007.

Table 2. Variability in May catch rates in the Charleston, SC, shipping entrance channel among principal index stations and years (2004-2007).

Year	month	Location	N Event	Net Hrs	N Caretta	CPUE
2004	May	A1	5	2.57	2	0.78
2004	June	A1	11	5.40	1	0.19
2004	August	A1	5	2.20	0	0.00
2005	May	A1	10	5.27	2	0.38
2005	August	A1	13	6.40	1	0.16
2006	May	A1	9	4.77	4	0.84
2004	May	A2	5	2.30	1	0.43
2004	June	A2	10	5.43	0	0.00
2004	August	A2	5	2.50	0	0.00
2005	May	A2	10	5.23	1	0.19
2005	August	A2	13	6.10	0	0.00
2006	May	A2	11	5.37	0	0.00
2004	May	A3	5	2.23	3	1.34
2004	June	A3	10	5.63	1	0.18
2004	August	A3	4	2.00	0	0.00
2005	May	A3	10	4.90	1	0.20
2005	August	A3	13	6.67	1	0.15
2006	May	A3	9	4.33	0	0.00
2004	May	B1	6	2.90	5	1.72
2004	June	B1	10	5.13	4	0.78
2004	August	B1	7	3.20	2	0.62
2005	May	B1	10	5.13	3	0.58
2005	August	B1	13	6.27	0	0.00
2006	May	B1	9	4.40	4	0.91
2007	August	B1	5	2.53	3	1.19
2004	May	B2	2	0.97	0	0.00
2004	May	B3	5	2.47	7	2.84
2004	June	B3	10	5.07	11	2.17
2004	August	B3	8	3.90	5	1.28
2005	May	B3	10	5.23	9	1.72
2005	August	B3	13	6.03	1	0.17
2006	May	B3	11	5.30	6	1.13
2007	May	B3	1	0.47	0	0.00
2007	August	B3	3	1.30	0	0.00
2004	May	D1	5	2.63	7	2.66
2004	June	D1	10	5.07	3	0.59
2004	August	D1	7	2.23	2	0.90
2005	May	D1	10	3.47	4	1.15
2005	August	D1	13	4.67	1	0.21
2006	May	D1	10	3.37	4	1.19
2007	May	D1	2	0.77	4	5.22
2007	August	D1	7	2.57	2	0.78
2004	May	D2	4	1.17	0	0.00
2004	May	D3	5	2.50	23	9.20
2004	June	D3	10	5.27	36	6.84
2004	August	D3	7	2.30	7	3.04
2005	May	D3	10	3.80	16	4.21
2005	August	D3	14	4.70	7	1.49
2006	May	D3	10	3.10	28	9.03
2007	May	D3	13	4.57	3	0.66
2007	August	D3	8	2.60	2	0.77
2004	May	E1	2	0.80	0	0.00
2004	May	E2	2	1.00	1	1.00
2004	May	E3	2	1.00	1	1.00

Size, Sex and Genetic Distributions, Canaveral

Of 128 live loggerheads collected in Canaveral in 2007, only 55 were processed to include measurements and blood collection for sex and genetics determination. Twenty-eight adult males ranged from 81.1 to 107.0 cm SCLmin, while seven adult females ranged from 87.8 to 95.5 cm SCLmin. Of 19 juvenile loggerheads processed, 15 were determined to be female and ranged in size from 59.3 to 79.7 cm SCLmin, while four were determined to be male and ranged in size from 62.9 to 75.1 cm SCLmin.

Of 50 blood samples collected for mitochondrial DNA analyses, 45 (90%) were of either the CC-A01 or CC-A02 haplotype. Two samples of haplotype CC-A03 were collected from an adult female and a juvenile female; haplotype CC-A10 was collected from a single adult female; and one sample each of haplotype CC-A04 and CC-A20 was collected from two adult males.

Size, Sex and Genetic Distributions, Charleston

Sex determination was possible for 13 of 14 juvenile loggerheads collected near Charleston in 2007. Eleven females ranged from 58.4 to 76.4 cm SCLmin, of which all but two were of the haplotype CC-A01; the two genetic exceptions among juvenile females included CC0437 (CC-A02) and CC0408 (CC-A14). Two juvenile males (60.8 and 62.2 cm SCLmin) were also collected and represented the CC-A01 and CC-A02 haplotypes, respectively. Sex could not be determined for one individual, which was 60.7 cm SCLmin and represented the CC-A02 haplotype.

Loggerhead Health, Canaveral

Nineteen of 55 (35%) loggerheads exhibited recent or healed wounds on the plastron, carapace, and/or flippers. Mating-related injuries were also noted for five adult males.

Total protein values ranged from 3.6 to 7.8 g/dL (mean = 5.6 g/dL) for adult loggerheads and from 2.2 to 4.6 g/dL (mean = 3.6 g/dL) for healthy juvenile loggerheads (note: one sick juvenile loggerhead had a field total protein value of 1.2 g/dL; however, pcv and blood glucose values did not suggest this turtle needed to be transferred to shore for rehabilitation). Total protein values for all but five adult loggerheads were equal to or greater than the maximum total protein for juvenile loggerheads.

Pack cell volumes (pcv) overlapped between juvenile (30 to 47) and adult (23 to 40) loggerheads; however, three juveniles had pcv values >40 (the maximum adult value) and seven adults had pcv values lower than 30 (the lowest juvenile value).

Blood glucose values overlapped considerably among juvenile and adult loggerheads, with blood glucose values for 71% (n=25 of 35) of adults and 76% (n=13 of 17) of juveniles ranging between 60 and 85 mg/dL. Six adult and four juvenile loggerheads had blood glucose values >85 mg/dL, while four adult and no juvenile loggerheads had blood glucose values <60 mg/dL.

Diagnostic blood profile data for adult male loggerheads collected in both 2006 and 2007 are presented in Table 3.

Table 3. Clinical values and descriptive statistics of blood parameters analyzed by Antech Diagnostic Laboratories for adult male loggerheads collected near Canaveral, FL.

Blood Chemistry	count	mean	min	max
Albumin	38	1.2	0.7	1.6
AST	38	166	79	360
BUN	38	33	16	88
Calcium	38	7.1	4.4	8.5
Chloride	38	116	105	125
CPK	38	1998	527	8543
Globulin	38	4.6	3.1	6.7
Glucose	38	74	37	133
Phosphorus	38	9	7	10.9
Potasium	38	4.7	3.3	6.2
Sodium	38	158	140	170
Total Protein	38	6	4	7.9
Uric Acid	38	0.5	0.1	1.5
Complete Blood Count	**count**	**mean**	**min**	**max**
WBC	38	10	4	15
Basophiles	38	0	0	2
Eosinophils	38	4	0	11
Heterophils	38	54	33	75
Lymphocytes	38	39	20	60
Monocytes	38	2	0	9
Azurophilic Monocytes	37	1	0	5
Absolute Basophils	38	35	0	160
Absolute Eosinophils	38	429	0	1210
Absolute Heterophils	38	5424	2300	9000
Absolute Lymphocytes	38	3861	1440	7840
Absolute Monocytes	38	208	0	900
Absolute Azuurophilic Monocytes	38	47	0	400
Pack cell volume	38	33	22	42

Loggerhead Health, Charleston

Ten of 14 juvenile loggerheads collected near Charleston exhibited pre-existing injuries or sickness. Six loggerheads were noted to have moderate to heavy barnacle loads and/or pronounced keratin sloughing. Blood values for two of these six loggerheads were low and similar (total protein = 1.6 g/dL; pcv = 19-25); however, only one of them (CC0440) visually appeared to be sick enough to warrant transfer for shore-based rehabilitation. Four additional loggerheads exhibited wounds to the carapace, head, neck and flippers.

Blood parameters evaluated at sea (total protein, glucose, pcv) for healthy juveniles were within normal ranges (Maier et al., 2004). Total protein values ranged from 2.4 to 4.6 g/dL (mean = 3.6 g/dL). Pack cell volumes ranged from 27 to 40 (mean = 32). Blood glucose values ranged from 66 to 139 mg/dL (mean = 94 mg/dL).

Blood chemistry and complete blood count data for Charleston loggerheads in 2007 were generally similar to values for Charleston loggerheads 2004-2006 (Table 4). Overlap in standard deviations for heterophils (and absolute heterophils), lymphocytes (and absolute lymphocytes) and absolute basophils indicated that slight differences in mean values for these parameters were not statistically different.

Table 4. Summary statistics for blood profile data for loggerheads collected in the Charleston, SC, shipping entrance channel during 2007 vs. 2004-2006.

	2007			2004-2006		
Blood Chemistry	**count**	**mean**	**stdev**	**count**	**mean**	**stdev**
Albu-AN	11	1.1	0.2	36	1.0	0.2
AST-AN	11	159	62	36	169	50
UrNi-AN	11	54	25	36	61	19
Calc-AN	11	6.8	1.2	36	7.1	0.9
Chlo-AN	11	119	6	36	117	5
CPK-AN	11	1114	818	36	1192	895
Glob-AN	11	3	1	36	2.5	0.8
Gluc-AN	11	93	17	36	89	20
Phos-AN	11	7.4	1.1	36	7.4	1.2
Pota-AN	11	4.6	0.4	36	4.5	0.5
Sodi-AN	11	157	3	36	158	4
ToPr-AN	11	3.9	0.9	36	3.5	0.8
Uric-AN	11	0.6	0.3	36	0.9	0.3
Complete Blood Count	**count**	**mean**	**stdev**	**count**	**mean**	**stdev**
WBC-AN	11	9	2	36	8	2
Baso-AN	11	0	1	36	1	1
Eosi-AN	11	3	4	36	4	4
HePo-AN	11	55	14	36	32	20
Lymp-AN	11	40	14	36	61	21
Mono-AN	11	1	1	36	2	3
AzMo-AN	11	0	1	34	1	1
AbBa-AN	11	16	54	36	50	82
AbEo-AN	11	320	432	36	270	292
AbPo-AN	11	5241	1908	36	2621	2016
AbLy-AN	11	3639	1166	36	5009	2250
AbMo-AN	11	133	110	36	183	280
AAMo-AN	11	15	48	34	63	146
Hema-AN	11	31	4	35	33	4

Sea Turtle Samples for Collaborators

Blood, plasma and skin biopsy samples from all adult male loggerheads were collected for Ms. Kimberly Reich (University of Florida) to conduct stable isotope analyses for evaluation of trophic foraging levels; however, results of analyses have not been received as of this writing. A biologist was hired in March 2008 to analyze mercury concentrations (Mr. Rusty Day, NIST) in blood and keratin samples collected from juvenile (*n*=35) and adult male (*n*=29) loggerheads which were satellite-tagged between 2004-2007; although results from these analyses are not available at this time, they will be included in the 2004-2008 Final Report which will be completed in November 2008. Similarly, graduate research support is being provided during summer and fall 2008 to analyze selected contaminant loads from blood samples collected for Dr. Jennifer Keller (NIST) during the same timeframe, the results of which should also be included in the Final Report. Analysis of barnacle samples collected for Dr. John Zardus (Citadel) during 2007 and 2008 will also be included in the 2004-2008 Final Report.

By-Catch, Canaveral

By-catch data were not recorded for trawling events in the Canaveral shipping entrance channel to increase available trawling time and to provide a safe working space on the back deck. As such, by-catch was released overboard immediately upon retrieval, which also increased the probability of survival. Notable by-catch species included consistently large catches (~15 per station) of smooth butterfly rays (*Gymnura micrura*).

By-Catch, Charleston

By-catch data were recorded for 28 trawling events. In addition to low turtle CPUE, associated by-catch was also minimal (Table 5).

Three shark species and five ray species were collected; however, only 21 specimens (all released alive) were collected in total. Four Atlantic sharpnose sharks (*Rhizoprinodon terranovae*) comprised 80% of all elasmobranch collections during the May cruise, whereas five blacknose sharks (*Carcharhinus acronotus*) and three blacktip sharks (*C. limbatus*) comprised 50% of all elasmobranch collections during the August cruise. The southern stingray (*Dasyatis americana*) was the most common ray species collected.

Eleven finfish species were noted; however, total individuals recorded as collected numbered fewer than 30 specimens. Banded drum (*Larimus fasciatus*) and Atlantic croaker (*Micropogonias undulatus*) comprised 59% of all finfish specimens documented.

Twenty invertebrate groupings were noted, with 214 total individuals recorded. Box jellyfish (Cubomedusae) comprised 59% of total invertebrate collections, whereas only one cannonball jellyfish (*Stomolophus meleagris*) was noted. Only 13 horseshoe crab (*Limulus polyphemus*) and seven blue crabs (*Callinectes sapidus*) were recorded.

Table 5. By-catch recorded during 28 trawling events near Charleston, SC in 2007.

	May Cruise			August Cruise	
Elasmobranchs	N coll	Sum		coll	sum
CARCHARHINUS ACRONOTUS				5	5
CARCHARHINUS LIMBATUS				3	3
RHIZOPRIONODON TERRAENOVAE	3	4			
DASYATIS AMERICANA				4	5
DASYATIS CENTROURA				1	1
DASYATIS SABINA	1	1			
GYMNURA MICRURA				1	1
RHINOPTERA BONASUS				1	1
Total		*5*			*16*

	May Cruise			August Cruise	
Finfish	N coll	Sum		coll	sum
CHLOROSCOMBRUS CHRYSURUS				2	1
SELENE SETAPINNIS				2	
STENOTOMUS ACULEATUS				1	
CYNOSCION NOTHUS				2	
LARIMUS FASCIATUS	2	8		2	1
LEIOSTOMUS XANTHURUS				1	
MICROPOGONIAS UNDULATUS				6	9
STELLIFER LANCEOLATUS	2	3			
PEPRILUS TRIACANTHUS				2	2
ANCHOA SP.	1	1			
PEPRILUS PARU	1	2		2	2
Total		*14*			*15*

	May Cruise			August Cruise	
Invertebrates	N coll	Sum		coll	sum
TUNICATA				2	5
APLIDIUM PELLUCIDUM				2	7
DEMOSPONGEA				4	9
PENAEUS AZTECUS				1	1
PENAEUS SETIFERUS	2	2			
PORTUNUS SPINIMANUS	2	2			
CALLINECTES SAPIDUS	7	7			
MENIPPE MERCENARIA				3	3
CALLINECTES SIMILIS	2	2		7	19
SQUILLA SP.	3	3			
LIMULUS POLYPHEMUS	6	10		2	3
STOMOLOPHUS MELEAGRIS				1	1
LEPTOGORGIA SP.				1	
CUBOMEDUSAE	3	4		20	123
ARBACIA PUNCTULATA				1	5
ALCYONIDIUM HAUFFI				1	4
BUSYCON CARICA	1	1			
BUSYCON CANALICULATA	1	1			
BUSYCON SP.	1	1			
LOLIGO SP.	1	1			
Total		*34*			*180*

Reproductive Status of Adult Male Loggerheads, Canaveral

The reproductive status of adult male loggerhead sea turtles was evaluated using a suite of methods including plastron softness analysis, ultrasound, testosterone, laparoscopy and testicular biopsy. The purpose of this phase of the research project was two-fold. The first objective was to assess the level of reproductive activity prior to satellite-tagging, in order to better understand the distribution patterns of adult male loggerheads collected at this location. Adult male loggerheads are known to occur year-round near Canaveral, with increased abundance in the spring (Henwood, 1987), when not all individuals are reproductively active (Wibbels et al., 1987). The second objective was to evaluate different methods (which vary in their degree of invasiveness and skill level required) for accurate assessment of the reproductive condition of adult male loggerhead sea turtles.

During ultrasound evaluation, kidneys were also observed, providing a point of reference when searching for the gonads. Testes were usually found between the intestine loops and the kidneys, and presented a homogeneous echopattern that was slightly hyperechoic to the kidney parenchyma (Figure 4). Testicular foldings could sometimes be observed. Epididymides were usually found caudal to the testes, between the testes and the kidneys; these appeared as a mass of many small tubular structures containing anechoic fluid, and suggested reproductive activity for the current breeding season (Figure 4). Ultrasound was easy to implement and results were immediately available, which minimized stress for the animal. However, when we were not able to visualize the epididymides by ultrasound, we could not be certain that this was simply the result of low reproductive activity or technical difficulty with the method. Thus, the lack of “tissue validation” limited the utility of this technique. In 2006, ultrasound determined 7 of 11 adult male loggerheads to be reproductively active (with poor imagery for four turtles); however, enhanced training improved determination capabilities, and 21 of 28 adult male loggerheads were determined to be reproductively active in 2007 (with poor imagery reduced to just 7 of 28 turtles).

Testosterone radioimmunoassay (RIA) was a slightly more invasive technique, as a 10ml blood sample was collected. Because subsequent laboratory analysis of this blood sample was required, results were not immediately available. Testosterone levels from plasma samples collected just after capture, in both 2006 and 2007, ranged from 1.23 ng/mL to 188.36 ng/mL. Three samples in 2006 and one in 2007 were below 5 ng/mL, and corresponded to the four turtles classified as reproductively inactive using laparoscopy and by histological analysis of the testicular biopsy samples. The average testosterone level for reproductively inactive males was 2.82 ± 0.66 ng/mL. The other 36 samples all came from reproductively active males and ranged from 16.66 to 188.36 ng/mL (mean = 113.15 ± 6.45 ng/mL). Furthermore, collection of a second testosterone sample following recovery from laparoscopy revealed a decline in testosterone values and a subsequent spike in corticosterone values (Table 7), highlighting the ability of steroid hormones to fluctuate greatly in short order. Thus, although testosterone data alone does not provide a complete analysis of reproductive condition of adult male loggerheads, all males with high testosterone levels were thought to be reproductively active. Low-testosterone males may represent non- or post-reproductively active males.

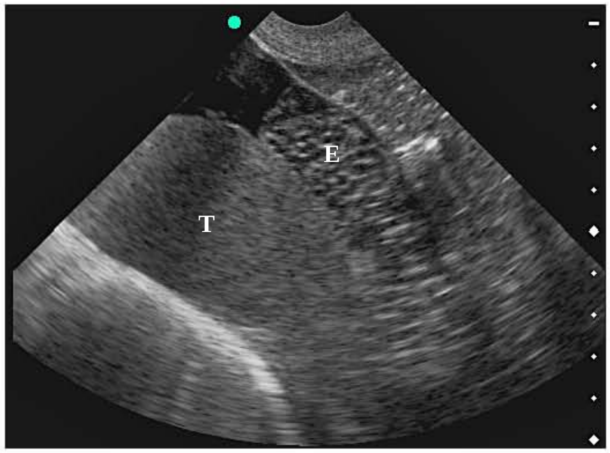

Figure 4. Ultrasound image of testis (T) and epididymis (E) from a reproductively-active adult male loggerhead sea turtle.

Table 6. Comparison of testosterone and corticosterone values from 28 adult males for which two blood samples were collected over time (including two recaptured turtles).

Turtle ID	Time Difference (h)	Testosterone 1	Testosterone 2	Corticosterone 1	Corticosterone 2
CC2452	*374 d earlier	124.9			
CC2452R	20.5	121	66	2.44	6.57
CC2464	9.9	145.3	99.7	0.74	5.91
CC2467	5.0	119.4	81.7	1.95	12.16
CC2468	20.3	1.3	0.79	2.55	23.73
CC2469		114.1		0.12	
CC2471	23.4	143.7	56	1.56	7.95
CC2472		182.9	174.6	0.95	6.41
CC2475	3.5	188.4	164.7	0.67	4.93
CC2476	23.2	129.4	83.7	0.71	3.8
CC2477	19.0	120.9	89.8	0.48	12.02
CC2486	29.9	104.6	106.8	0.57	4.73
CC2486R	* 20 d later	72.6		1.06	
CC2487	55.7	124.5	88.6	0.66	13.96
CC2492	4.6	140.5	113.8	0.32	4.57
CC2494	33.3	109.2	91.4	0.31	5.54
CC2496	6.5	81.1	71	0.37	5.67
CC2497	19.1	118.5	66	1.3	2.58
CC2499	19.5	96.8	54.4	0.85	2.78
CC2500	18.0	149.3	96.9	1.37	7.58
CC2503	20.3	65.4	46.7	0.67	3.37
CC2505	19.2	85.9	48.9	0.5	4.87
CC2507	4.6	144.4	103.8	1.24	13.85
CC2509	20.7	20.6	12.9	0.77	2.12
CC2510	3.3	53.1	50.9	2.23	13.84
CC2511	5.2	59.4	57.7	1.82	12.73
CC2512	3.1	108.9	106	6.14	9.81
CC2513	5.7	110.6	94.4	1.41	6.14
CC2514	4.6	16.7	13.7	1.11	10.24
CC2516	3.4	96	97.1	1.25	14.35

Laparoscopic analysis proved to be a more powerful tool than ultrasound to evaluate reproductive status. Despite being a considerably more invasive technique, the testis was directly observed in all cases, and epididymides were visualized in all but one male in 2006. The epididymides appeared as white convoluted tubules, full of sperm, and the testis appeared turgid (Figure 5) in all but four cases. Thrice in 2006 and once in 2007, the testis looked regressed and the epididymides were atrophic (Figure 6), so these turtles were classified as being reproductively in-active using this technique. These three turtles also had low testosterone levels (Table 7).

Table 7. Summary of reproductive assessment data from 38 adult male loggerhead sea turtles (including two recaptured individuals) from the Port Canaveral, FL, shipping entrance channel in April 2006 and 2007.

Year	Turtle ID	Disposition	Testosterone (ng/mL)	Ultrasound	Laparoscopy	Testis Biopsy	Mean Plastron softness
2006	CC2442	Migrate to SC	112.0	Active	Active	Active - mild	46.43
2006	CC2443	Unknown	124.7	Active	Active	Active - mild	50.37
2006	CC2444	Resident	3.3	Active	Moderately active	Active - minimal	34.00
2006	CC2445	Migrate to MD	172.0	Active	Active	Active - moderate	32.87
2006	CC2446	Resident?	2.4	Not seen	Not active	Not active	8.17
2006	CC2450	Migrate to NJ	123.5	Not seen	Active	Active - minimal	
2006	CC2452	Resident	124.9	Active	Active	Active - moderate	38.67
2007	CC2452R		121.0	Active	Active	NA	41.90
2006	CC2453	Resident	4.3	Not seen	Not active	Not active	37.83
2006	CC2456	Migrate to NJ	147.5	Active	Active	Active - moderate	
2006	CC2457	Unknown	136.1	Not seen	Active	Active - mild	55.27
2006	CC2462	Unknown	110.6	Active	Active	Active - moderate	20.67
2007	CC2464	Unknown	145.3	NA	Active	Active-Stage 6	30.33
2007	CC2467	Resident	119.4	NA	Active	Active-Stage 6	41.97
2007	CC2468	Resident	1.3	NA	Not active	Not active-Stage 2	
2007	CC2469	no sat tag	114.1	NA	NA	NA	34.27
2007	CC2471	Unknown	143.7	Active	Active	Active-Stage 7+	51.20
2007	CC2472	no sat tag	182.9	NA	NA	NA	37.53
2007	CC2475	Migrate to NC	188.4	NA	Active	Active-Stage 7+	47.13
2007	CC2476	Resident	129.4	NA	Active	Active-Stage 6	36.27
2007	CC2477	Unknown	120.9	Active	Active	Active-Stage 6	28.33
2007	CC2486	Migrate to n FL	104.6	Active	Active	Active-Stage 7+	50.23
2007	CC2486R		72.6	Active	Active	Active-Stage 7	57.83
2007	CC2487	Migrate to FL Keys	124.5	Active	Active	Active-Stage 6	25.43
2007	CC2492	Resident	140.5	Active	Active	Active-Stage 7+	35.93
2007	CC2494	Migrate to FL Keys	109.2	Active	Active	Active-Stage 6	41.20
2007	CC2496	Migrate to n FL	81.1	Active	Active	Active-Stage 6	45.97
2007	CC2497	Resident	118.5	Active	Active	Active-Stage 6	45.80
2007	CC2499	Resident	96.8	Active	Active	Active-Stage 7	33.27
2007	CC2500	Migrate to NC	149.3	Active	Active	Active-Stage 7	49.17
2007	CC2503	Migrate to Andros Is.	65.4	Active	Active	Active-Stage 7+	50.97
2007	CC2505	Migrate to SC	85.9	Active	Active	Active-Stage 6	41.87
2007	CC2507	Migrate to NC	144.4	Active	Active	Active-Stage 6	50.10
2007	CC2509	Migrate to VA	20.6	Active	Active	Active-Stage 7	34.13
2007	CC2510	no sat tag	53.1	Active	NA	NA	
2007	CC2511	Migrate to VA	59.4	Active	Active	Active-Stage 7	56.47
2007	CC2512	no sat tag	108.9	Active	NA	NA	
2007	CC2513	no sat tag	110.6	Active	NA	NA	
2007	CC2514	no sat tag	16.7	Active	NA	NA	
2007	CC2516	no sat tag	96	Active	NA	NA	

Testicular biopsies proved to be a powerful tool in determining the reproductive status of the adult loggerhead males. Each sample was classified into spermatogenetic stages based on Meylan et al. (2002). Seminiferous tubule maximum diameters were measured using the microscope and recorded to the nearest 10 microns for a minimum of three tubules per turtle. Mean tubule diameter was 135.7 ± 8.2 μ (n = 3) and 359.8 ± 8.8 μ (n = 25) for reproductively-inactive and -active males, respectively. With the exception of four individuals the first year for which we did not have enough material to make a conclusion (including one turtle classified as inactive during laparoscopy), we found that three males were inactive, as observed during laparoscopy (stage 1 of the spermatogenesis, small tubule diameter). All other males were stage 5 – 7+ ("post-spermatogenic", see Figure 7), clearly demonstrating that they were reproductively-active that season.

In conclusion, an assortment of reproductive data (serum testosterone, ultrasound, laparoscopy and testicular biopsy) suggested that all but three of 11 (2006) and all but one of 20 (2007) adult male loggerheads collected were reproductively-active. We found that some adult males did not show any signs of reproductive activity, which suggests that they may have a multi-annual reproductive cycle, just as females do. Laparoscopy and testis biopsy provided the most powerful assessments of reproductive condition. Testosterone analysis separated the active males from the inactive males in two distinct groups, with titers of the inactive males < 5 ng/mL, and titers of the active males much higher, reaching 188 ng/mL in some instances. This technique could be used to evaluate the reproductive status of adult males, however, it can not be used in the field at this time, as it requires several days of laboratory work. Also, testosterone analysis would have to be done on samples collected during the pre-mating season, as testosterone levels decrease drastically during mating and thereafter, as suggested in this study, with the much lower titers measured in males captured the last week of April 2007.

A B

Figure 5. Laparoscopic image of epididymides (A) and testis (B) from a reproductively *active* adult male loggerhead sea turtle.

A B

Figure 6. Laparoscopic image of epididymides (A) and testis (B) from a reproductively-*inactive* adult male loggerhead sea turtle.

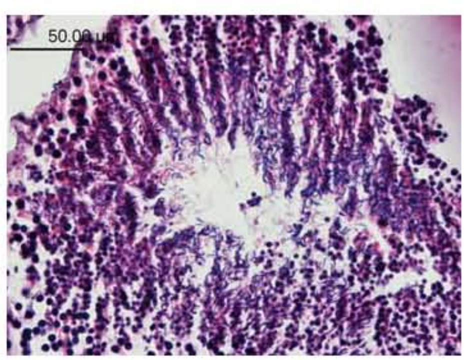

Figure 7. Histological image of a testis in stage 6 (numerous sperm cells) from a reproductively active adult male loggerhead.

Satellite Telemetry, Overview
In April 2007, 20 adult male loggerheads were tagged and released with satellite transmitters in two groups (2-6 April; 25-29 April) near Cape Canaveral, FL. Adult male loggerheads (*n*=10) satellite-tagged during 2-6 April ranged in size from 86.8 to 107 cm SCLmin, which were of similar size (86.9 to 102.5 cm SCLmin) as 10 adult male loggerheads satellite-tagged during 25-29 April. Eleven juvenile loggerheads were tagged and released with satellite transmitters in two groups (21-22 May; 31 July-1 August) near Charleston, SC. Six juvenile loggerheads satellite-tagged during May were smaller (58.5 to 70.7 cm SCLmin; four < 63 cm SCLmin) than five juvenile loggerheads satellite-tagged in July and August (60.8 to 76.8 cm SCLmin; four > 67 cm SCLmin). A twelfth juvenile loggerhead (64.2 cm SCLmin) was satellite-tagged and released from Jekyll Island, GA, following rehabilitation at the GA Sea Turtle Center.

Data collection periods were variable but similar for both adult male (33 to 356 days; mean = 169 days) and juvenile (47 to 361 days; mean = 148 days) loggerheads. Data collection periods in 2007 were not noticeably different from data collection periods observed between 2004 and 2006 (Figure 8). Spring-only data was collected for five adult male loggerheads in 2007, while maximum data collection ran through the summer for seven additional adult male loggerheads. Maximum data collection through the fall occurred for five additional adult male loggerheads, while data collection in all four seasons was only possible for three adult male loggerheads. Summer-only data was collected for six juvenile loggerheads released in 2007, while maximum data collection through the fall occurred for three juvenile loggerheads. Data collection in all four seasons was only possible for three juvenile loggerheads released in 2007.

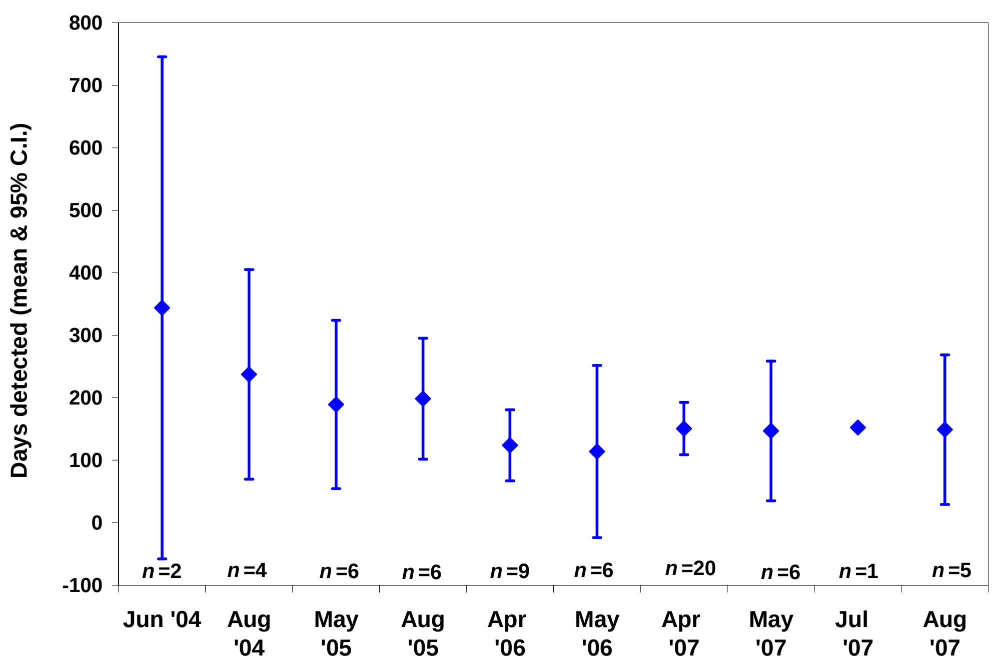

Figure 8. Data collection periods per loggerhead release groupings, 2004-2006. All release groupings except for April 2006 and 2007 (adult males) are juvenile loggerheads.

Satellite Telemetry, Adult male loggerheads

Of 10 adult male loggerheads satellite-tagged during the 2-6 April cruise, three ultimately transited away from Canaveral; three remained resident near Canaveral; and data collection for four males ceased prior to the end of June. However, in late April and early May, two of these four adult males (CC2468, "Chris" and CC2477, "JJ") moved to areas occupied by long-term resident males in 2006 and 2007, suggesting residency.

During April and through mid-May, "good" location class data (Argos LC 1, 2 and 3) indicated that both resident and transient adult male loggerheads were generally located within 15km of shore (Figure 9). This pattern of near-shore distribution continued through the first half of May (Figure 10); however, by 2 June 2007, all known transients had departed the area and known residents moved further offshore than where they had been located up to six weeks prior (Figure 11).

Among transient males, one (CC2475, "Quattro") moved north to Cape Hatteras, NC, where it was detected until 5 August (124 days, Figure 12). Two other transient males from the 2-6 April group headed south, with one (CC2487, "Keller") relocating to the southern FL Keys where it was detected until 5 August (122 days), while a second male (CC2486, "Tony") relocated to the Big Bend area of the FL Panhandle where it was detected until 26 March 2008 (356 days, Figure 13).

Three adult males (CC2476, "Jim"; CC2467, "Stanford"; CC2492, "Montgomery") remained resident near Canaveral for at least one to two months after moving offshore (Figure 14). Data collection for these three adult male loggerheads ceased on 6 July (94 days), 15 July (105 days), and 13 August (134 days), respectively.

Of 10 adult males satellite-tagged between 25 and 29 April, eight transited away from Canaveral (Figure 12, 13), while two remained resident (Figure 14); residents were detected until 24 August (CC2499, "McCoy") and 26 October (CC2497, "Dr. Abt"). Three transient adult males traveled south. The first (CC2503,"Dean") became localized on the SW side of Andros Island in the Caribbean, where it was detected until 24 August (118 days). Two other males became localized in the FL Keys (CC2494, "Ligouri") and near Fort Walton Beach in the FL Panhandle (CC2496, "Hokie"). These males were tracked until 10 November (198 days) and 22 February 2008 (304 days), respectively.

Five adult males traveled north. One male (CC2505, "Austin") became localized on the inner shelf near Pawleys Island, SC, and was detected there until 24 October (180 days). One male (CC2500, "Ingle") became localized near Cape Hatteras, NC, and was detected there until 14 November (202 days). Two other males (CC2507, "Stortz"; CC2509, "Cougar") became localized near the VA/NC border, with "Cougar" also briefly residing within the Chesapeake Bay. Data collection for both "Stortz" and "Cougar" ceased on 16-17 August, after 111 days of detection. One male (CC2511, "Elvis") became localized on the mid-shelf east of the Chesapeake Bay, where it remained until 8 November before swimming to the southwest for the next three weeks until becoming localized approximately 100 km east of Cape Fear, NC, where it was last detected on 20 March 2008 (327 days).

Satellite Telemetry, Juvenile loggerheads

Four of six juvenile loggerheads released during 21-22 May remained localized near Charleston (with most “good” locations between Capers Island and Kiawah Island) for the duration of detection (Figure 15). Contact with all four of these juvenile loggerheads was lost between 4 August (75 days) and 24 September (124 days).

Two juvenile loggerheads released during 21-22 May immediately departed the Charleston area. The first, ID73116 (“Pearse”), headed south to the inland waterways of St Helena Sound, where it remained for several weeks before resuming a second rapid southerly course into GA waters, where it remained somewhat localized until being last detected on 7 September (113 days; Figure 16). The second juvenile loggerhead (ID73114, “Glenn”) traveled north after release and entered Delaware Bay less than two months later (Figure 17). This turtle remained in Delaware Bay for the next 3.5 months, before a six-week transit south to the waters offshore of Onslow Bay, NC. After over-wintering off NC, this turtle resumed a northerly course, arriving in the Chesapeake Bay in early May, where it was detected for the next two weeks with the last known location (16 May 2008; 361 days) near the mouth of the Potomac River.

A 64.2 cm SCLmin loggerhead (ID49618, “Golden Boy”) was released from the Georgia Sea Turtle Center on Jekyll Island, GA, on 19 July 2007, after spending more than 10 months in captivity for treatment for “Debilitated Turtle Syndrome”. For the first three weeks following release, “Golden Boy” remained localized in coastal waters between St. Simon Island and Cumberland Island (Figure 18). Between mid-August and mid-December, a slow southerly course was observed with extended residence (weeks) in several locations between the GA/FL border and St. Augustine, FL. Between 13 and 18 December, a more rapid southerly movement was initiated; however, data ceased abruptly on 18 December, after 152 days at large.

Two of five juvenile loggerheads released between 31 July and 1 August remained localized near Charleston (with all “good” locations offshore from Folly and Kiawah Islands) for the duration of detection (Figure 15). Contact with both of these juvenile loggerheads was lost between 16 September (47 days) and 4 October (64 days).

Movement away from Charleston was documented for three juvenile loggerheads released between 31 July and 1 August (Figure 19). One loggerhead (ID73121, “Kevin”) exhibited a very atypical pattern, initially swimming to Holden Beach, NC, before resuming a southerly course to the middle and outer continental shelf waters off central GA and ultimately nearing the GA/FL border on 18 December (137 days). A second loggerhead (ID73120, “Stingray”) remained between Charleston and Cape Romain, SC, until 15 November, before swimming south to over-winter on the middle continental shelf off central GA; “Stingray” began swimming north again on 14 April 2008, reaching the waters offshore of Fripp Island, SC, when last detected on 1 May 2008 (248 days). The third loggerhead (ID73123, “Kelly”) initially traveled north to Cape Lookout, NC, where it remained for nearly three weeks before rapidly resuming a southerly course to an area approximately 80-100 km east of Cape Fear, NC, where it remained until 4 April 2008 after 247 days of detection.

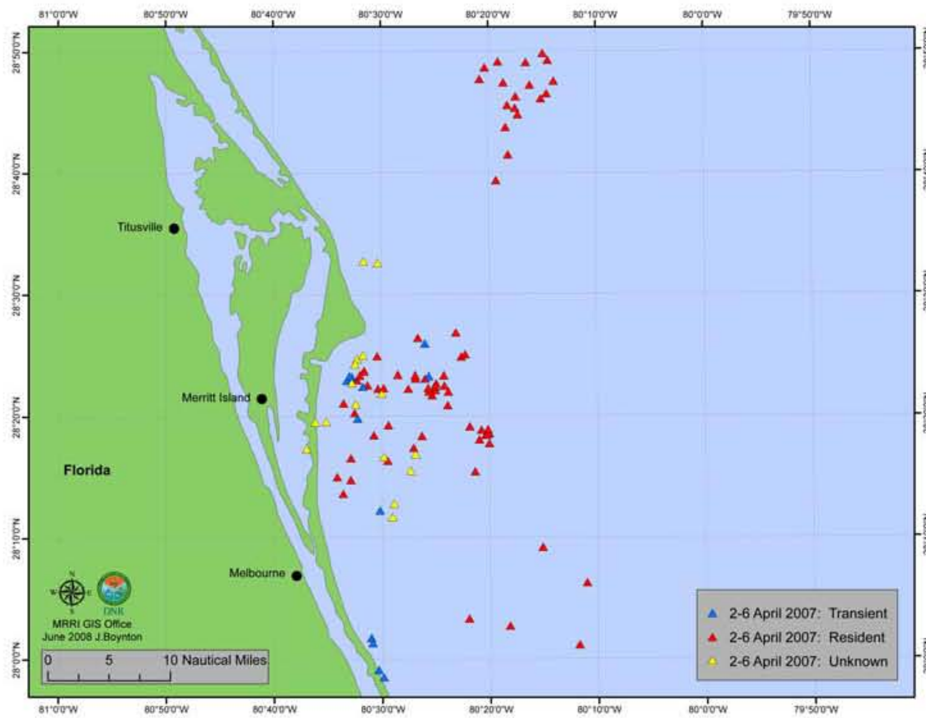

Figure 9. Spatial distribution of "good" Argos locations for adult male loggerheads near Cape Canaveral, FL, between 2 and 24 April 2007.

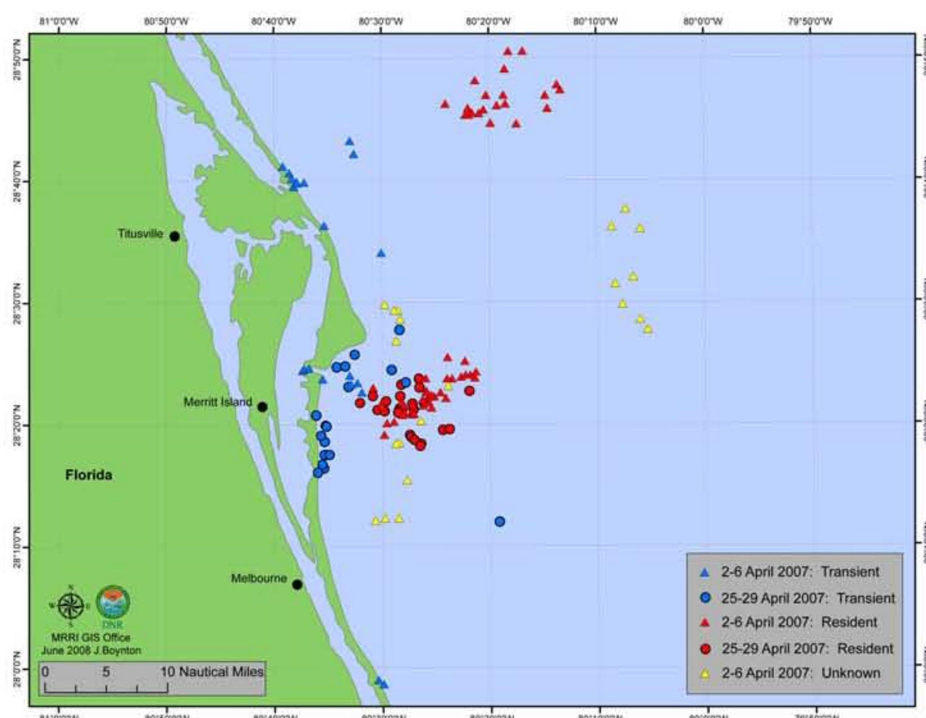

Figure 10. Spatial distribution of "good" Argos locations for adult male loggerheads near Cape Canaveral, FL, between 25 April and 15 May 2007.

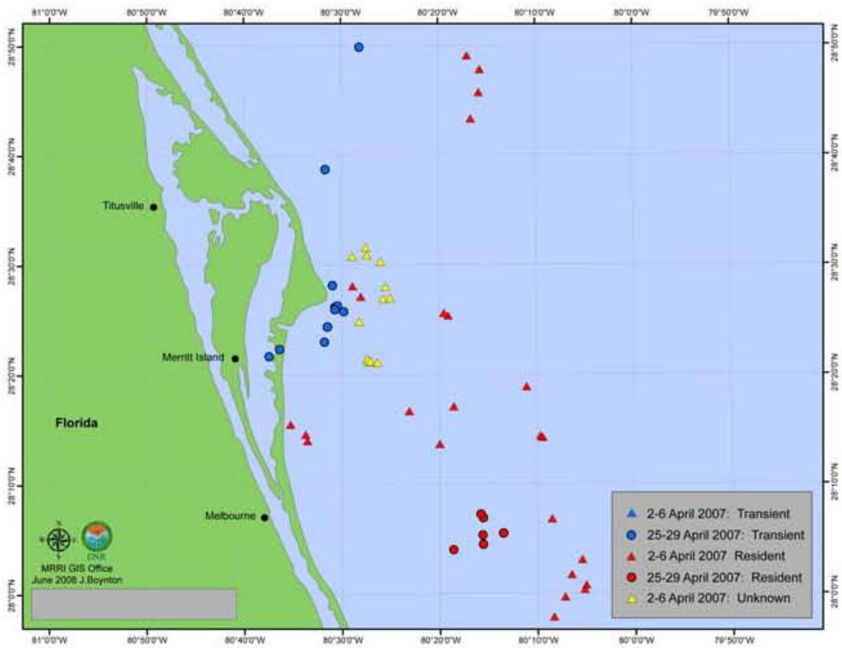

Figure 11. Spatial distribution of "good" Argos locations for adult male loggerheads near Cape Canaveral, FL, between 16 May and 2 June 2007.

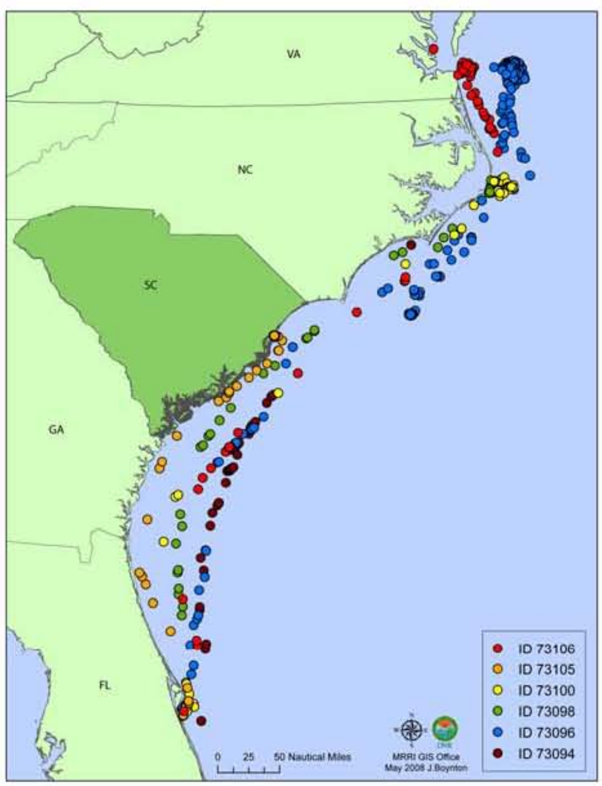

Figure 12. Spatial distribution of "good" Argos locations for adult male loggerheads that traveled north from Cape Canaveral, FL, following completion of mating in 2007.

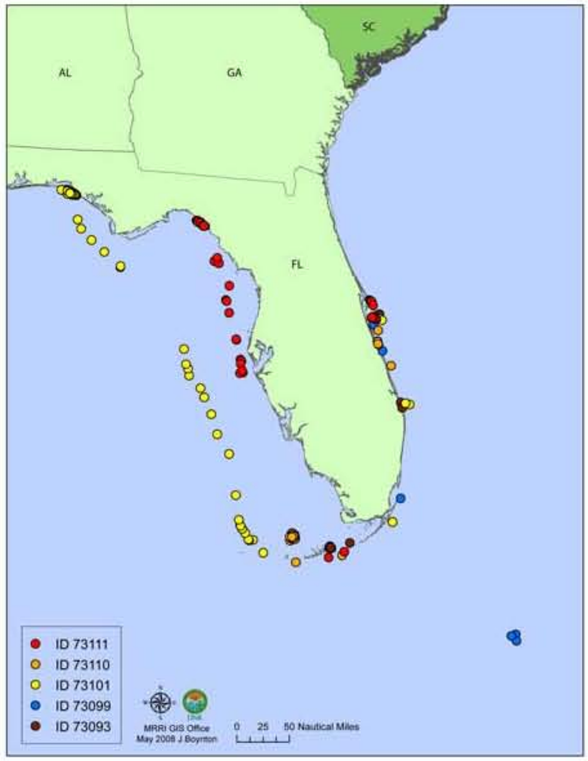

Figure 13. Spatial distribution of "good" Argos locations for adult male loggerheads that traveled south from Cape Canaveral, FL, following completion of mating in 2007.

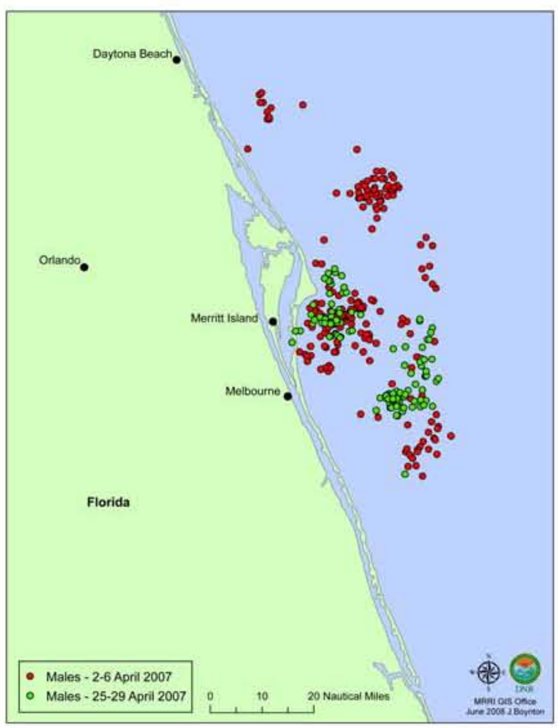

Figure 14. Spatial distribution of "good" Argos locations for adult male loggerheads that remained near Cape Canaveral, FL, following completion of mating in 2007.

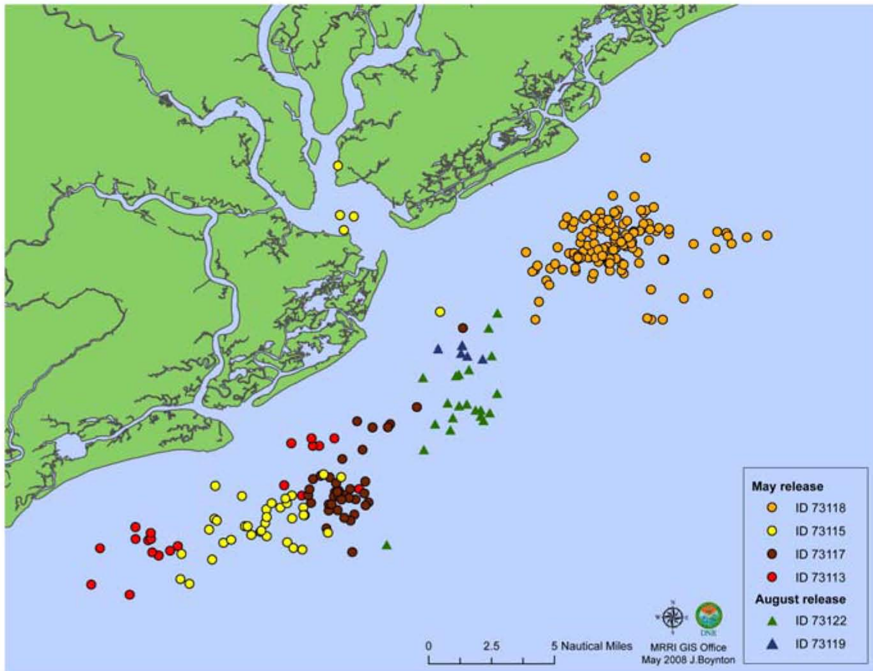

Figure 15. Spatial distribution of "good" Argos locations for juvenile loggerheads which remained localized near Charleston, SC, in 2007.

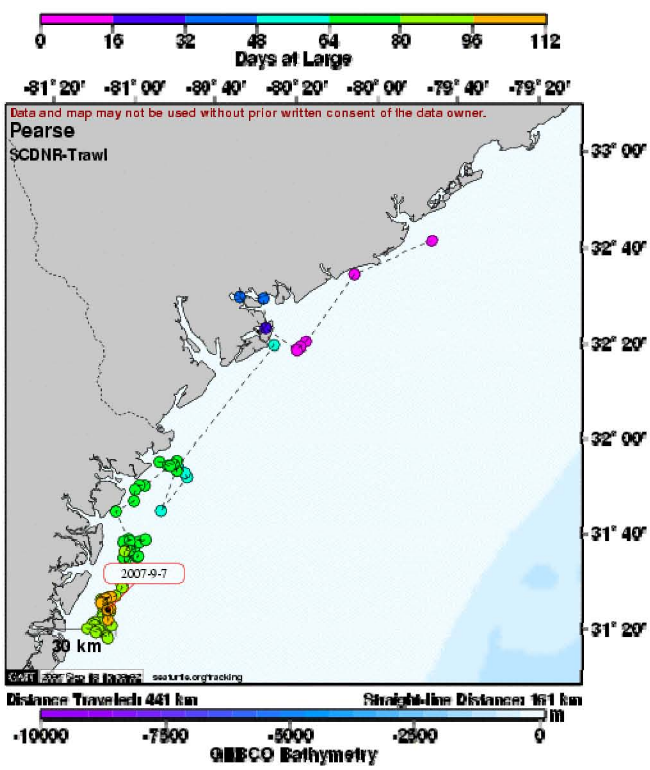

Figure 16. Movement patterns of juvenile loggerhead ID73116 ("Pearse") during 113 days of detection following tag and release on 22 May 2007.

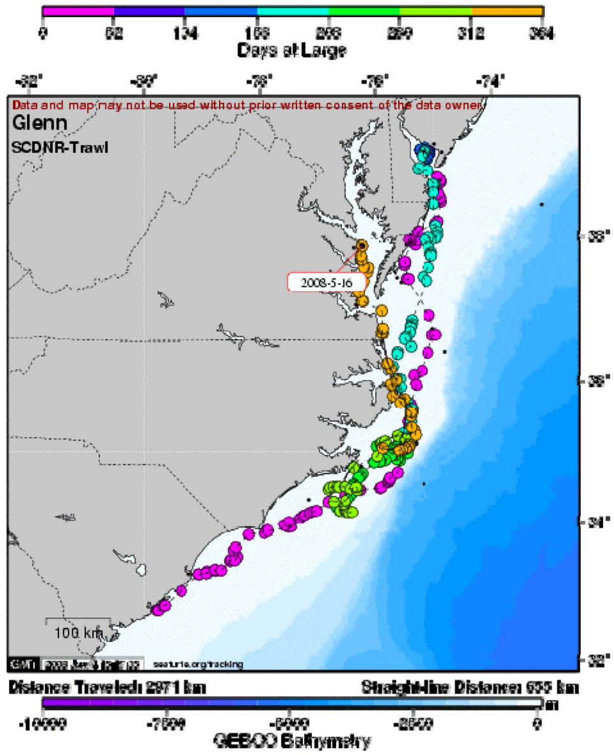

Figure 17. Movement patterns of juvenile loggerhead ID73114 ("Glenn") during 361 days of detection following tag and release on 22 May 2007.

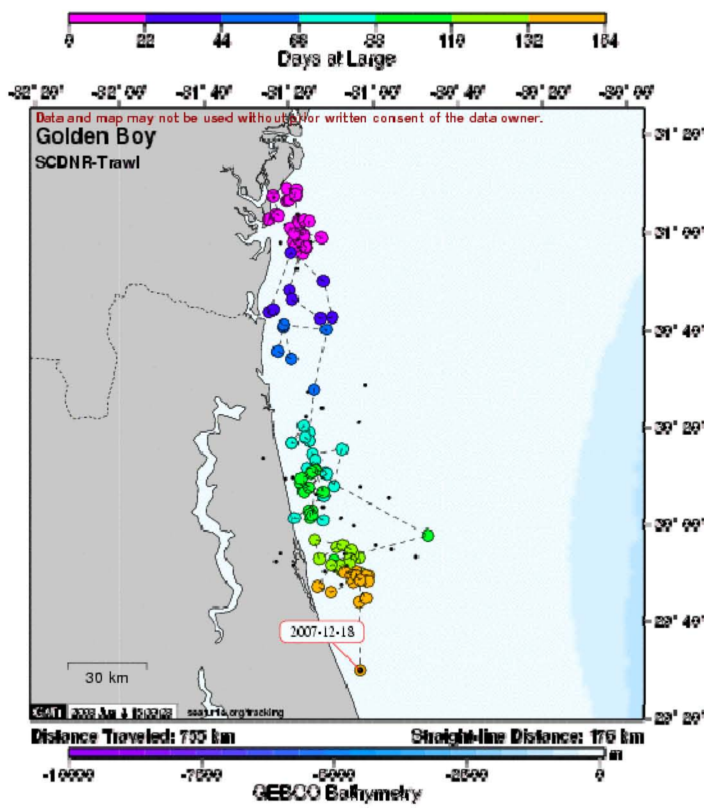

Figure 18. Movement patterns of juvenile loggerhead ID49618 ("Golden Boy") during 152 days of detection following tag and release on 22 May 2007.

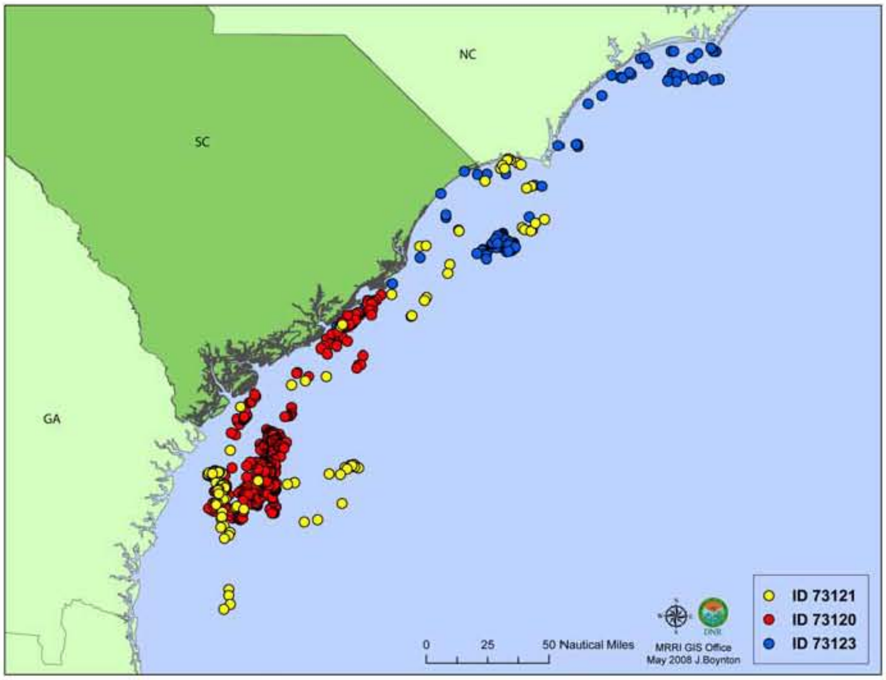

Figure 19. Spatial distribution of "good" Argos locations for juvenile loggerheads which did not remain localized near Charleston, SC, following tag and release in 2007.

Discussion

Charleston

Loggerhead (and overall by-catch) rates during both May and August sampling periods were unusually low, with loggerhead catch rates comparable to rates noted during sampling in May and August 1990 at this same location (VanDolah and Maier, 1993). Loggerhead catch rates noted in May 2005, 2006 and 2007 continue to be well below loggerhead catch rates noted during this study in May 2004. Exceptionally warm water temperatures associated with May 2004 sampling have also not been observed during May sampling in any of the subsequent three years. Furthermore, given that loggerhead catch rates did not increase to May 2004 levels in subsequent years when a perceived increase in the relative abundance of blue crabs, an important prey item, was noted, water temperature may be a more important factor for increasing loggerhead catch rates at this location. However, given the paucity of loggerheads and blue and horseshoe crabs collected in May 2007, prey availability should also not be ruled out as a critical variable.

Low recapture rates (*n*=8 of 218; 3.7%) in the current research study continue to suggest low site-utilization within the confines of the channel. Indeed, low site-utilization is corroborated by satellite telemetry data sets for 34 juvenile loggerheads monitored to date following tag and release immediately after capture, even for loggerheads only monitored for up to one month. Following capture and release, satellite-tagged loggerheads generally remain within 30 km of the channel. As such, loggerheads may periodically re-visit the channel during the summer and fall, and the channel appears to be an important landmark for satellite-tagged turtles tracked through the winter, which often orient to the channel during the spring re-migration.

Immediate and long-distance movement away from Charleston following tag and release by two juvenile loggerheads in May and three juvenile loggerheads in August was atypical with respect to 2004-2006. Size distribution among these five highly mobile loggerheads spanned the range of sizes typically observed; thus, turtle size is not suspected as a factor which influenced movement of these loggerheads. With respect to sex and genetic origin, all five were female and with the exception of one loggerhead with a CC-A14 haplotype, these other loggerheads were of the most common haplotype (CC-A01) observed in the northern sub-population. Furthermore, the sole genetic outlier in this group of highly mobile loggerheads was a turtle that was originally caught and released in the Charleston shipping channel 15 months earlier. Given low total catch rates noted in both May and August, it is possible that movement of these turtles could have been related to food availability rather than intrinsic factors. Initial reports from the SEAMAP shallow bottom trawl survey during spring 2007 indicated that catch rates for many finfish species between Cape Hatteras, NC, and Cape Canaveral, FL, were also lower than usual; however, the Annual Report for that study is unavailable at this time.

Canaveral
The significance of the Port Canaveral shipping entrance channel (which has only existed since the mid 1950's) to the life cycle of loggerhead sea turtles along the U.S. Eastern Seaboard has been recognized for at least thirty years. The potential of this channel as a regular over-wintering habitat for loggerhead sea turtles received attention after juvenile loggerheads were collected there in the winter of 1978 (Carr et al., 1980). Subsequent trawling studies have documented year-round collection of loggerheads in this channel, with seasonal shifts in the size and sex ratios of loggerheads collected (Henwood, 1987; Dickerson et al., 1995). The almost assuredness of catch has prompted other researchers to target loggerheads at this location to assess a variety of population parameters including health (Lutz and Dunbar-Cooper, 1987; Wibbels et al., 1987; Bolten et al., 1992; Crain et al., 1995) and physiology (Wibbels et al., 1987); relative abundance (Butler et al., 1987; Schmid, 1995); vessel interactions (Dickerson et al., 1991; Ehrhart, 1987); and local distribution patterns (Kemmerer et al., 1983; Nelson et al., 1987; Standora et al., 1993a,b).

Although only 61 trawling events were completed between April 2006 and April 2007, a definitive 'hot spot' for adult male loggerheads was noted between buoy pairs "3/4" and "5/6". This finding is consistent with year-round trawling efforts conducted by Dickerson et al. (1995), who observed greatest CPUE (in excess of 2.5 turtles per hour) in their station "3", which roughly corresponds to the area between these buoy pairs. Similar to Dickerson et al. (1995), trawling in April 2006 was also conducted in the middle of the channel. High densities of loggerheads near buoys "5" and "6" is also reported by Bolten and Bjorndal (1990). In 2007, adult female and juvenile loggerheads were collected more frequently at the next station inshore of buoys "5" and "6"; thus, given trawl durations of 15 minutes at typical towing speeds of 2.6 kts, it is possible that loggerheads from both of these trawling blocks could have been located very close together, and simply caught at the beginning or end of a respective trawl tow.

In contrast to patterns noted for juvenile loggerheads from the Charleston, SC, shipping entrance channel, many “good” locations for adult male loggerheads appeared to be in the confines of the channel where they were collected, particularly through the end of April. Additional “good” satellite locations during these two weeks included the near-shore waters off of Cocoa Beach, and as far south as the southern end of the Archie Carr National Wildlife Refuge. These observations provide more information on habitat utilization patterns for adult males collected from the Canaveral channel than were previously available from a month-long monitoring study of radio-tagged animals within 10km of shore, in which only three adult males were included and data only collected on two of them for up to 2 days (Kemmerer et al., 1983). From the available literature it is uncertain whether or not additional data were collected during a subsequent study involving one of the same authors the following spring (Nelson et al., 1987). Short-term (20-48 h post-release) but intensive acoustic tracking of adult male loggerheads collected in the Port Canaveral channel in spring 1993 documented initial movement away from the channel followed by a return to within a 3.5km radius (Ryder et al., 1994).

Transient adult male loggerheads moved rapidly away from Canaveral during a consistent two week window between mid-May and early June in both 2006 and 2007. Of 15 adult males that moved away from Canaveral between the two years, two-thirds (*n*=10) traveled to the north to very specific and localized destinations which were spread nearly evenly along the Eastern Seaboard between SC and NJ. Adult female loggerheads satellite-tagged on nesting beaches in the Southeastern U.S. are also reported to move to some of the same locations which are presumed to be important post-nesting foraging grounds (GADNR, unpublished; SCDNR, 1). Five of the 15 highly mobile adult male loggerheads traveled south, with three becoming highly localized in tropical waters (FL Keys, Andros Island) while two others became localized in the nearshore and inshore waters off the FL Panhandle. Given that all transient adult males reached summer foraging grounds by the end of June and early July, and that these summer foraging grounds were within the range of known nesting habitat for loggerheads in the Western Atlantic Ocean and Gulf of Mexico, it is theoretically possible that these adult males could have continued to breed with adult female loggerheads which would have nested on beaches adjacent to male summer foraging grounds. As such, our data would seem to support the concept of male-mediated gene flow that occurs via wide geographic immigration by males to established mating areas and multiple paternities within the same clutch of eggs. This patternhas been reported for green and flatback sea turtle species (Fitzsimmons et al. 1997, Moore and Ball 2002), but to date, has not been confirmed for loggerheads.

Data that documents the potential for annual reproductive activity in adult males (i.e., one adult male that was reproductively active in both years) is limited; however, mating may not occur in the same location annually. Three transient adult males exhibited extended residence at localized foraging grounds hundreds of kilometers away from Canaveral through late winter and early spring 2008. Because historical trawling data document that dramatic increases in catch rates for adult males begin in late winter (Wibbels et al., 1987), our observations would suggest that while adult males may be capable of mating annually, they might not travel great distances to do so annually.

Distributional data from this study document greater north-south migration distances than previously reported for adult male loggerheads. Prior to the current study, known north-south movements by adult male loggerheads occurred on scales of less than four degrees of latitude (~450km). Two rehabilitated adult male loggerheads satellite-tagged in the fall near the VA/NC border over-wintered off the coast of southern NC prior to re-emigration to the Chesapeake Bay the following spring (Keinath, 1993). Adult male loggerheads satellite-tagged in Florida Bay have been documented to migrate as far north as central FL during the mating season; however, most of nearly 20 adult male loggerheads satellite-tagged at that location to date have remained much more localized (Schroeder, personal communication). Off the coast of Japan, two adult male loggerheads (<80cm straight-line carapace length) have also been satellite-tagged following incidental capture in coastal set nets. Although track lengths varied (35 days vs. 115 days), both turtles utilized the Kushimoto Current, which transported them offshore and generally between latitudes 29°N and 33°N (Sakamoto et al., 1997; Hatase et al., 2002). For the longer track, the turtle traveled more than 2,100 km during Jan-May before returning to coastal waters for the mating season (Sakamoto et al., 1997).

Although the occurrence of adult male loggerheads in the Port Canaveral shipping channel during spring has predominantly been associated with mating activities, previous researchers have suspected, based on tag-recapture (Henwood, 1987) and low serum testosterone levels (Wibbels et al., 1987), that resident males also comprise some portion of the spring aggregation. As many as 14 of 29 adult male loggerheads satellite-tagged in this study may have remained resident near Canaveral year-round, moving between inshore breeding grounds and middle to outer continental shelf foraging grounds. Year-round residence offers both energetic as well as genetic advantages, the latter of which are circumstantially supported by our data. Specifically, a great proportion of resident (or likely resident) males were collected earlier in the mating season (cruise 1, 2007) than later in the mating season (cruise 2, 2007), whereas the ratio of resident to transient males was nearly evenly split during a temporally intermediate cruise in 2006. However, it must be taken into consideration that sample size for satellite-tagging in all three cruises was low (n=9 to 10). Nonetheless, in addition to longer tracking durations associated with adult male loggerheads satellite-tagged later in the mating season, our limited results to date suggest a greater probability for encountering transient males later in the mating season, and future research addressing dispersal patterns may wish to keep this in mind.

Multiple methods used to determine the level of reproductive activity of adult male loggerheads suggest that reproductive activity is independent of transient or resident dispositions. Testosterone levels may fluctuate widely on short temporal scales; although low testosterone values can not be automatically interpreted to represent non-reproductive activity, high testosterone values do indeed reflect reproductive activity. Improved familiarity with the use of ultrasound increased the value of this technique during the second year of the study. In 24 instances when ultrasound suggested reproductive activity, laparoscopic data were in agreement; however, in four instances when ultrasound data were inconclusive, laparoscopic data was evenly split between activity and non-activity. Thus, with sufficient expertise, ultrasound offers a non-invasive technique for confirming (though not necessarily refuting) reproductive activity.

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